

Effects of seismic shaking on grain size and density sorting with implications for constraining lunar regolith bulk composition

Lillian R. Ostrach and Mark S. Robinson
NLSI Lunar Science Forum 2010
July 22nd, 2010

Scientific Objective

Remote sensing techniques measure different depths within the regolith

→ Regolith: fragmental debris overlying largely coherent rock (e.g., Oberbeck et al., 1973; Shoemaker et al., 1969)

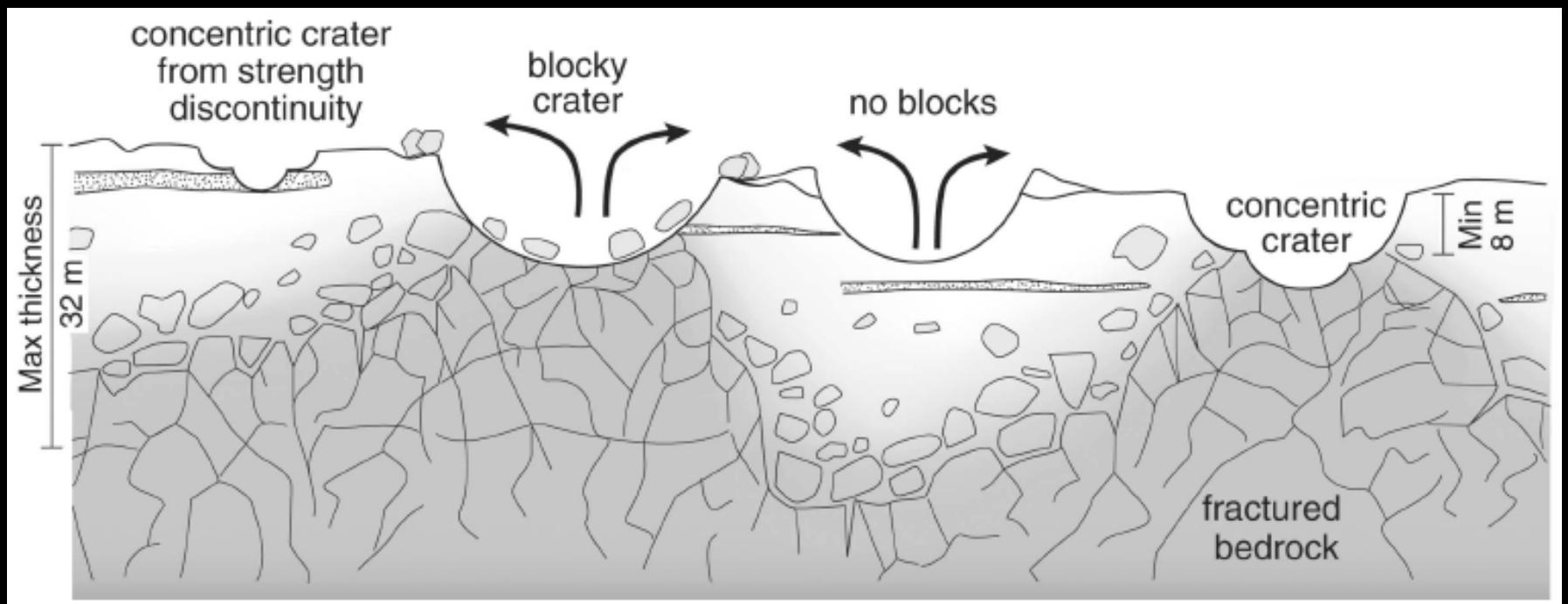


Fig. 12, Wilcox et al., 2005

Work Statement

GOAL: determine whether the lunar regolith exhibits compositional sorting at the few 100 μm to 10 cm depth scale during EITHER ejecta emplacement or later seismic events

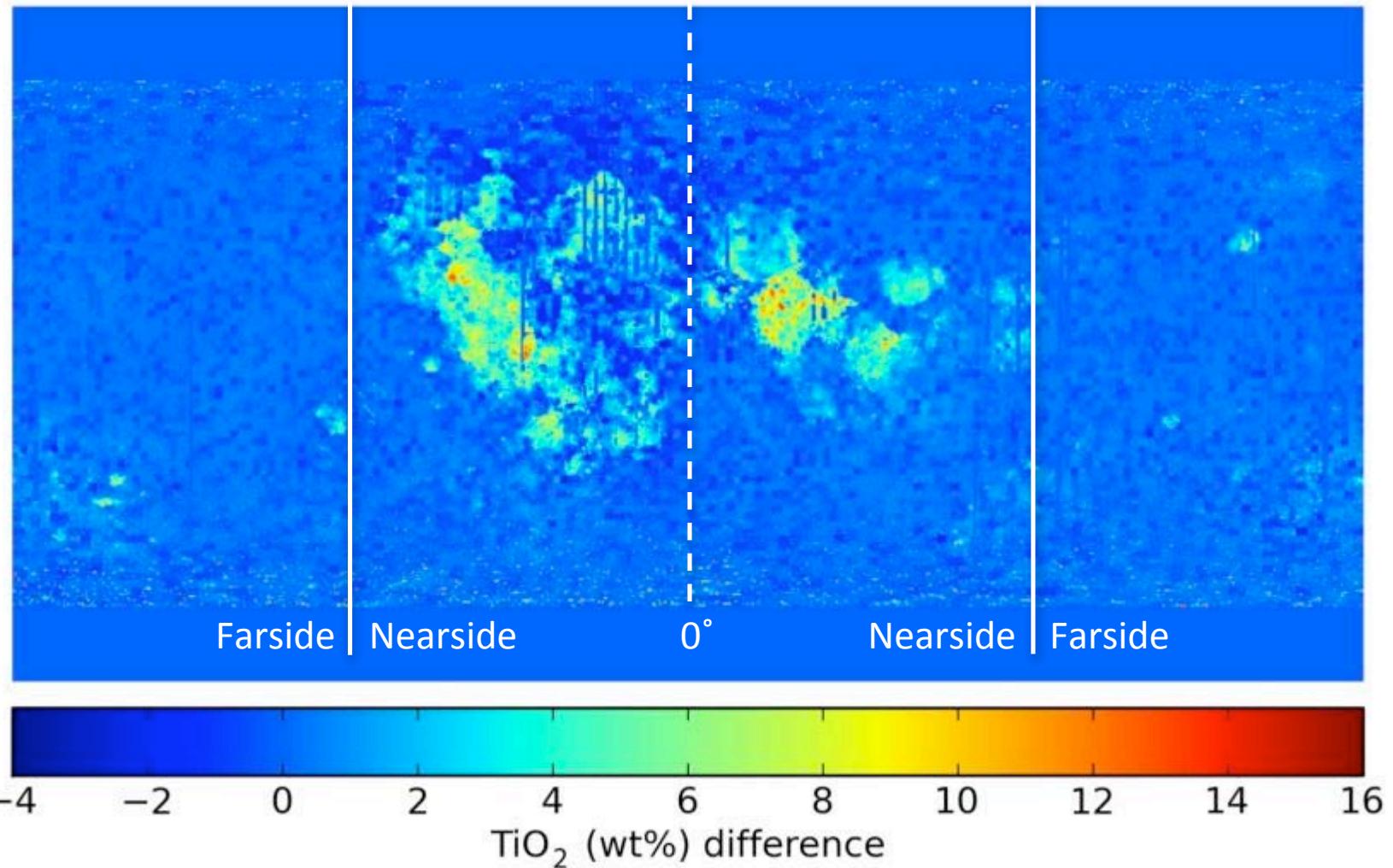
QUESTION: Does ilmenite content of the optical surface differ from the subsurface?

Introduction

- How does regolith form?
 - Comminution: impacts break down rocks
 - Agglutinates: aggregates of smaller particles glued with impact melt from micrometeorites
- Basic lunar mineralogy – mostly silicates, oxides
 - Olivine $(\text{Fe}, \text{Mg})_2\text{SiO}_4$ $\rho=3.80$ g/cc (avg)
 - Pyroxene $(\text{Ca}, \text{Fe}, \text{Mg})_2\text{Si}_2\text{O}_6$ $\rho=3.54$ g/cc
 - Plagioclase feldspar $(\text{Ca}, \text{Na})(\text{Al}, \text{Si})_4\text{O}_8$ $\rho(\text{An})=2.76$ g/cc
 - Ilmenite $(\text{Fe}, \text{Mg})\text{TiO}_3$, reflects high TiO_2 contents in mare basalts (original magma) $\rho=4.74$ g/cc

Background

Clementine - Lunar Prospector TiO_2 Difference Map



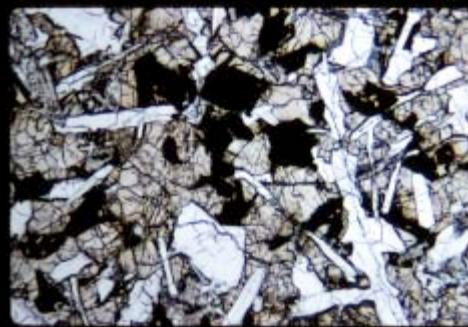
Do the differences in TiO_2 reported represent true compositional vertical stratification?

Background

- Apollo 17 sample 75055: high-Ti mare basalt
 - Medium-/fine-grained, elongated, subhedral ilmenite grains ($\sim 120 - 400 \mu\text{m}$) with pyroxene and plagioclase crystals (Meyer, 2008); 12% ilmenite
(Dymek et al., 1975) $\rho(\text{il})=4.74 \text{ g/cc}$

- Comminution rates may vary (e.g., Papike et al., 1982; Hörz et al., 1984; McKay et al., 1991; Papike et al., 1991; Lucey et al., 2006)

Image credit: ASU



5.3mm

PPL



XPL

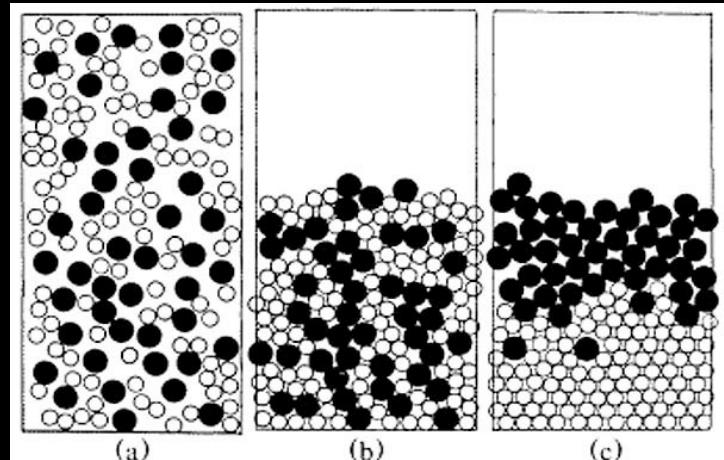
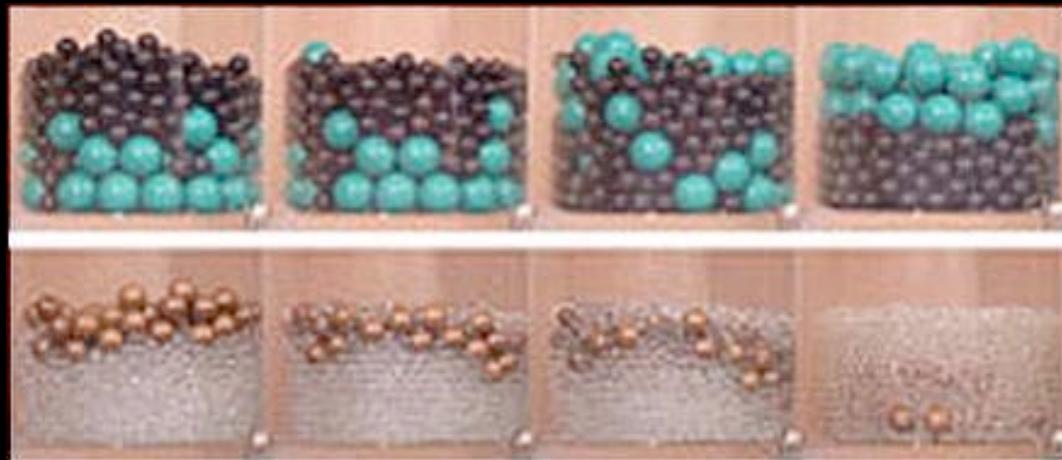
Background

Kinetic sieving, “Brazil-Nut Effect”:

Large particles move to the top

Experiments

Numerical Modeling



Top: 8 mm brown glass, 15 mm blue polypropylene

Bottom: 10 mm bronze, 4 mm clear glass

$$\rho(\text{bronze}) = 8.9 \text{ g/cc}$$

$$\rho(\text{glass}) = 2.5 \text{ g/cc}$$

$$\rho(\text{polypropylene}) = 1.5 \text{ g/cc}$$

Breu et al., 2003

Black sphere: $D=1.5D$ (white)

Rosato et al., 1987

Experimental Setup



Ilmenite
 $\rho=4.70\text{-}4.78 \text{ g/cc}^*$



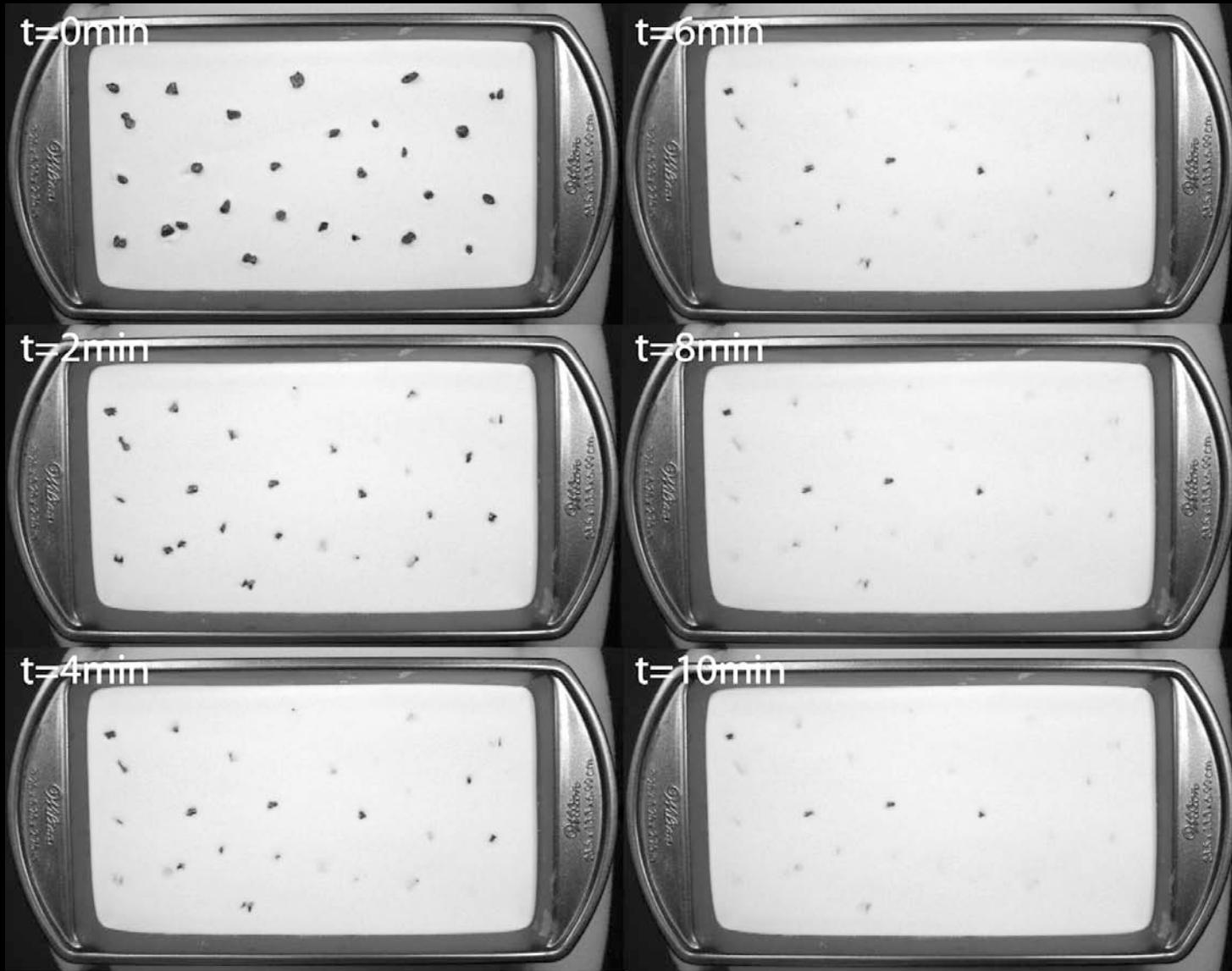
Basalt
 $\rho=2.40\text{-}3.10 \text{ g/cc}$

Glass beads, $\rho=2.46\text{-}2.49 \text{ g/cc}$



Initial Results

Ilmenite, $\rho=4.70-4.78 \text{ g/cc}$



Experimental Setup 2



Syntron Jogger VP-181
Tabletop dimensions 30" x 30"
Pan inner diameter 28"

Ilmenite, anorthosite pieces >4 mm
Sand 300 – 600 µm
Anorthosite hand sample 9 cm across



Interpretations & Implications

- Grain-size sorting is influenced by density
- Different densities of minerals should promote density-driven sorting in the regolith
- “Brazil-Nut Effect” may not be applicable to geologic materials except when materials have same density
 - Experiment: representative of geologic materials?
How does the fluidized regime affect behavior?

Future Work

- Test range of grain size and density contrasts
- Calculate rate and depth of descent; compaction of fine-grained component
- Test sorting in a non-fluidized regime: horizontal shaking (box 44" x 44")
- Understand dynamics of ejecta emplacement – when/where does sorting occur?



LROC NAC M111599349R; crater diameter is 120 m [Image credit: NASA/GSFC/ASU]

